

Internet Development, Population Aging and Urban-rural Income Gap: An Empirical Analysis Based on Provinces in China

Jianing Xu¹, Aili Zhang² and Qian Chen³

Abstract

This study utilizes panel data from Chinese provinces spanning 2013 to 2021 to establish a comprehensive evaluation index system for the level of Internet development. It investigates the impact of Internet development and its sub-dimensions on the urban-rural income gap and further examines the moderating effect of population aging. The findings suggest that Internet development can significantly improve the urban-rural income gap by increasing the farm and non-farm incomes of rural residents. Specifically, from a sub-dimension perspective, Internet infrastructure, commercial scale, and development potential play significant roles in narrowing the income gap, with substantial effects observed. Moreover, considering regional heterogeneity, the narrowing effect of the Internet on the urban-rural income gap in the Northeast, Central, and Western regions is significant and roughly equivalent, surpassing that of the Eastern region. Population aging leads to synchronous changes in the age structure of Internet users; the "silver-haired digital divide" impedes the elderly population's access to and use of the Internet, thereby inhibiting the shrinking effect of Internet development on the urban-rural income gap. Further investigation reveals that the imbalance in the urban-rural population aging process, with the degree of rural aging outpacing urban areas, is a significant factor contributing to this inhibitory effect.

Keywords: Urban-rural Income Gap, Internet development, Population Aging, Moderating effect.

¹ Applied Economics Department, College of Economics & Management, Beijing University of Technology, China.

² Applied Economics Department, College of Economics & Management, Beijing University of Technology, China.

³ Applied Private Enterprise Liaison Service Center in Qufu City, Shandong Province, Qufu, China.

1. Introduction

The rapid economic growth in China has enhanced the quality of life and income levels for residents. However, the persistent urban-rural income gap remains a significant challenge hindering the high-quality development of the Chinese economy, largely due to the influence of the traditional dual economic structure between urban and rural areas. Compared to urban areas, rural areas face obstacles such as inefficient circulation of production factors, weak development foundations, and relatively singular development structures, resulting in a substantial income gap between urban and rural residents. With the rapid development and continuous upgrading of digital information technologies such as artificial intelligence, cloud computing, big data, and 5G, the widespread development of Internet technology provides a new solution for narrowing the urban-rural income gap. The development of the Internet optimizes agricultural production decisions, facilitates sales circulation channels, and increases farmers' operational income, making it a crucial breakthrough point in addressing rural and agricultural development issues. However, the development and application of the Internet are also constrained by the issue of population aging. Factors such as physical and cognitive decline hinder the widespread adoption of the Internet among the elderly population, with individuals aged 60 and above accounting for as much as 37.4% of non-Internet users in China⁴. The difficulty of digital inclusion of the elderly is a pressing issue in the development of the Internet to alleviate the urban-rural income gap. Therefore, clarifying the role and mechanism of Internet development in narrowing the urban-rural income gap under the backdrop of population aging is essential. This understanding can help optimize and adjust the direction and strategy of Internet development in China, further leveraging its inclusive poverty alleviation effects and promoting the timely realization of common prosperity.

In recent years, considerable scholarly attention has been directed towards examining the impact of internet development on rural-urban income disparity. Some studies posit that internet development will narrow the rural-urban income gap. On one hand, the advent of the internet era has broken the constraints of information transmission and reduced search costs (Ji et al., 2023), leading to a greater increase in wage income for rural residents compared to urban residents (Gao et al., 2018), thereby narrowing the rural-urban income gap. On the other hand, the rise of rural e-commerce has expanded sales channels, streamlined intermediary processes, reduced transaction costs, overcome the geographic constraints of tangible markets (Peng et al., 2021), and increased farmers' income from agricultural operations, thus bridging the rural-urban income gap. However, some studies suggest that rural residents with lower levels of education (Forman et al., 2012) are unable to fully leverage the digital dividends of the internet, resulting in a rural-urban digital divide that widens the rural-urban income gap (Liu, 2017). Furthermore, there is research indicating a non-linear trend, depicted as a "reverse

⁴ The data comes from the 51st Statistical Report on the Development Status of China's Internet published by the China Internet Network Information Center (CNNIC).

U-shaped" or "U-shaped," in the impact of internet development on rural-urban income disparity (Chen and Wu, 2021). In studies related to population aging and rural-urban income disparity, some argue that population aging will widen the rural-urban income gap through changes in labor endowment and increased caregiving burdens (Wang et al., 2017), as well as skewed human capital and changes in savings structure (Yao, 2021). Conversely, other research suggests that the transition towards an aging population structure may narrow the rural-urban income gap through cost incentive effects, income effects, and substitution effects (Zeng and Jiang, 2020).

Focusing on the measurement of internet development, early studies predominantly utilized single indicators for evaluation, such as internet penetration rate (Wang and Cao, 2019), number of internet users (Bojnec and Fertö, 2015 and Choi, 2010), and broadband subscriptions (Tian and Feng, 2023). As research progressed, more scholars began employing comprehensive indicator systems to comprehensively explore the level of internet development. Wang et al. (2022) opted to construct an Internet Development Index from both input and output dimensions of the internet, incorporating indicators such as internet penetration rate, internet-related employment, internet-related output, and mobile internet usage, thus offering a more nuanced evaluation of regional internet development status. Meanwhile, Li and He (2019) adopted eight secondary indicators to assess regional internet development levels across five dimensions: infrastructure, technological application, talent pool, investment level, and economic benefits.

In summary, existing research exhibits the following shortcomings: (1) Many studies predominantly rely on intermittent years of the China Family Panel Studies (CFPS) data to examine the impact of internet development at the micro-level of households, which results in a lack of coherence and comprehensiveness; (2) The ongoing trend of population aging continues to deepen, with profound implications across various aspects of socio-economic dynamics. Yet, there remains a dearth of research considering how population aging affects the role of internet development in shaping the rural-urban income gap; (3) Measurement of internet development levels often relies on singular indicators, and even in studies employing comprehensive evaluation frameworks, internet development is frequently presupposed as a static process.

The potential marginal contributions of this study are as follows: First, by utilizing continuous panel data, it aims to empirically examine the impact of internet development on rural-urban income disparity from a more continuous and comprehensive macro perspective. Secondly, this study aims to thoroughly consider the intensifying backdrop of population aging, revealing how population aging moderates the process of internet narrowing rural-urban income gap, and the role played by the disparity in rural-urban aging processes within this context. Third, it intends to establish a comprehensive evaluation framework for internet development levels based on a dynamic developmental perspective, incorporating the data-carrying capacity and future development potential of the internet. Furthermore, it aims to delve into the role of internet development in narrowing rural-urban income gap from a segmented dimension perspective.

2. Theoretical mechanisms and research hypothesis

2.1 The Role of Internet Development in Narrowing Rural-Urban Income Gap

The development of the internet facilitates the flow of information, breaking down barriers to access and reaching relatively secluded rural areas. Consequently, it enhances the efficiency of resource allocation in education, society, and the economy, thus bridging the physical gap between urban and rural economies and facilitating China's traditional dualistic economic structure, ultimately reducing the rural-urban income gap (Zeng, 2019). Specifically, internet development plays a positive role in narrowing rural-urban income gaps through two channels: increasing agricultural income for rural residents and facilitating non-agricultural entrepreneurial employment opportunities.

On one hand, internet development increases agricultural income for rural residents. From the demand side, with the integration of internet technology and rural industries, rural e-commerce has become one of the significant channels for agricultural product distribution. Rural e-commerce supported by internet technology enhances rural residents' market participation (Ogutu et al., 2014), enabling agricultural producers to connect directly to online markets, broaden sales channels, reduce intermediary costs, increase sales prices, mitigate information asymmetry issues (Ullah et al., 2023), and directly augment rural residents' agricultural income, thus narrowing the rural-urban income gap. From the supply side, internet development assists farmers in accurately obtaining market demand information (Leng, 2022), optimizing production decisions and plans, lowering production costs, enhancing productivity (Wang et al., 2024), promoting agricultural industry upgrading (Nawab et al., 2022), and reducing income gap between rural and urban residents. Additionally, internet development can optimize agricultural industry structure by promoting technological innovation, fostering industry integration, and facilitating industrial transformation and upgrading, thereby revitalizing rural economies and narrowing rural-urban income gap.

On the other hand, internet development increases non-agricultural employment and entrepreneurial income for rural residents. Firstly, the widespread adoption of internet technology expands channels for information acquisition and dissemination, enhancing the value of information (Demertzis et al., 2018). This leads to improvements in rural residents' ideologies, educational levels, and other aspects (Xie et al., 2023), thus narrowing the gap in human capital between urban and rural labor forces and contributing to the amelioration of rural-urban income gap. Secondly, internet development assists rural job seekers in accessing relevant job information (Min et al., 2020), thereby reducing search and matching transaction costs and narrowing the information gap between urban and rural labor forces, which in turn improves rural-urban income gap. Lastly, internet development has spurred the emergence of new financial mechanisms such as digital inclusive finance, effectively addressing the financing and lending challenges faced by rural residents due to the scarcity and backwardness of traditional financial institutions

(Zhang and Cai, 2021). This enables farmers to choose from a variety of entrepreneurial options based on their conditions and aspirations, consequently reducing rural-urban income gap. In summary, this leads to the first hypothesis in this paper.

Hypothesis 1: *Internet development will narrow the rural-urban income gap.*

2.2 The Moderating Effect of Population Aging on the Impact of Internet Development on Rural-Urban Income gap

As population aging intensifies, demographic shifts lead to a corresponding change in the age structure of internet users. Age is a crucial factor influencing internet development and usage. With advancing age, cognitive abilities decline, and learning capabilities diminish among the elderly population, resulting in lower levels of digital literacy and potential difficulties and resistance in accessing and using the internet (Yuan and Jia, 2021). This gives rise to a phenomenon known as the "senior digital divide," which subsequently impacts the internet's ability to contribute to income augmentation and poverty reduction. From an individual difference perspective among elderly populations in urban and rural areas, urban seniors generally possess distinct advantages over their rural counterparts in terms of education level, willingness to learn, and physical and mental health (Yuan et al., 2023). Consequently, urban elderly individuals exhibit significantly higher rates of internet access and usage compared to rural elderly individuals. This amplifies the influence of population aging on the income augmentation and poverty reduction effects of the internet in rural areas, thereby inhibiting the mitigating effect of internet development on rural-urban income gap. On the other hand, considering the disparity in the aging processes between urban and rural areas, uneven development in education, healthcare, and economic sectors prompts rural-to-urban migration, predominantly driven by labor force movement. China's imbalanced urban-rural aging process manifests in rural areas experiencing higher levels and rates of aging compared to urban areas (Li and Wu, 2020). Rural areas have a higher proportion of older people than urban areas, making it more difficult for the Internet to fulfill its role. This leads to the second and third hypotheses in this paper.

Hypothesis 2: *The deepening degree of population aging will inhibit the effect of the internet in narrowing rural-urban income gap.*

Hypothesis 3: *Disparities in the urban-rural aging process are a significant reason for how population aging inhibits the internet's role in reducing rural-urban income gap.*

3. Research Design

3.1 Variable design

3.1.1 Dependent variable

The urban-rural income gap (URID) is measured following the approach of previous scholars (Ge et al., 2022), which involves calculating the ratio of per capita disposable income for urban residents to per capita disposable income for rural residents to gauge urban-rural income gap. Considering the distortion of real income caused by differential urban and rural inflation rates, this study employs urban and rural Consumer Price Index to eliminate the impact of inflation on urban and rural disposable income, respectively.

3.1.2 Independent variable

Internet development (INT) is measured in this study by referring to relevant research findings on internet development levels both domestically and internationally. Following the spiral-up development path of internet construction, diffusion, application, and re-development, this study innovatively introduces evaluation indicators measuring information resources and future development potential from the perspective of dynamic internet development. It constructs an indicator system comprising four primary indicators (infrastructure, data carrying capacity, commercial scale, and development potential) and twelve secondary indicators. For detailed information, please refer to Table 1.

Infrastructure serves as the fundamental support for providing digital information and technology over the internet, constituting the earliest stage of internet development. It is assessed through indicators such as mobile telephone switch capacity, density of long-distance optical cable routes, broadband internet access ports, and the proportion of IPv4 addresses to gauge the state of internet infrastructure construction. Data carrying capacity reflects the effective information resources the internet carries, which is crucial for its continuous development. The richness of internet-provided information is gauged using indicators such as the number of web pages and the total number of bytes on web pages. The proportion of dynamic web pages to total web pages evaluates the timeliness and activity of internet information. Commercial scale directly reflects the level of application of internet technology services in economic activities, reflecting the willingness of both supply and demand sides to accept internet technology and services. Indicators such as the number of websites per hundred enterprises, the number of enterprises engaged in e-commerce transactions, and e-commerce sales volume are used to measure the scale of internet-enabled digital transactions in commercial activities. Development potential embodies the potential capacity of the internet to upgrade information, technology, and service quality, with human and financial investment serving as fundamental guarantees for advancing internet development and upgrades. Human input and financial input are respectively represented by the number of urban employees in information transmission, software, and information technology services industries, as well as fixed asset investment. The entropy

method is employed to process data for these twelve refined indicators and calculate the internet development index for each region.

Table 1: Comprehensive evaluation index system of internet development level

Primary Indicator	Secondary Indicator	Unit
Internet Infrastructure (INF)	Mobile telephone exchange capacity	Ten thousand households
	Density of long-distance optical cable routes	Kilometers per square kilometer
	Internet broadband access ports	Ten thousand
	Proportion of IPv4 addresses	%
Data Carrying Capacity (IFD)	Number of web pages	One
	Number of bytes per web page	One
	Proportion of dynamic pages to total web pages	%
Commercial Scale (CMS)	Average number of websites per one hundred enterprises	One
	Number of enterprises engaging in e-commerce transactions	One
	E-commerce sales volume	One hundred million yuan
Development Potential (PFD)	Number of urban employees in the information transmission, software, and information technology services industry	Ten thousand people
	Fixed asset investment in the information transmission, software, and information technology services industry	Ten thousand yuan

3.1.3 Moderating variables

(1) Population Aging (OLD): The proportion of the population aged 65 and above in a region is used to measure population aging. A higher proportion of the elderly population indicates a deeper level of population aging in the area.

(2) Disparity in Urban-Rural Population Aging (UROD): The difference between the proportion of the population aged 65 and above in rural areas and the proportion of the population aged 65 and above in urban areas is used to measure the disparity in population aging between urban and rural areas. It indicates the level at which rural aging exceeds urban aging in the region.

3.1.4 Control variables

(1) Industrial Structure (IND): The proportion of the sum of the value added of the secondary and tertiary industries to GDP is used to measure industrial structure. With structural optimization, the shift from the primary industry to the secondary

and tertiary industries, along with the outflow of labor, alleviates rural-urban land constraints, enhances agricultural productivity, increases rural per capita income, and contributes to narrowing the rural-urban income gap.

(2) Level of Foreign Direct Investment (FDI): The proportion of total foreign direct investment (FDI) to GDP in the region is used to measure the level of foreign investment. Inflows of FDI generate accumulation effects of human capital and technology spillover effects, which are more significant in rural areas than in urban areas. Moreover, FDI increases non-agricultural income for farmers. Hence, the improvement in economic development due to FDI inflows is significantly greater in rural areas than in urban areas, thereby narrowing the rural-urban income gap.

(3) Government Expenditure (GOV): The proportion of general budgetary fiscal expenditures of each province to GDP is used to measure government expenditure. In many rural areas, social security benefits lag behind those in urban areas, with urban residents receiving significantly higher levels of transfer payments and welfare income compared to rural residents. The positive effects of government expenditure are more pronounced in urban areas, leading to a widening gap in income between urban and rural residents.

3.2 Sample selection and data sources

Based on data availability, this study selects panel data from 31 provincial-level regions in China from the years 2013 to 2021 as the research sample. The data used are sourced from the "China Statistical Yearbook," "China Population and Employment Statistics Yearbook," "China Internet Development Report," and "China Third Industry Statistics Yearbook." Descriptive statistics for each variable are presented in Table 2.

Table 2: Descriptive statistics of the variables

Variable	Mean	Std.	Min	Max
URID	2.6840	0.4027	1.8417	3.8220
INT	0.3584	0.2556	0.0375	1.5603
IND	0.9041	0.0522	0.7473	0.9978
FDI	0.7505	3.5117	0.0480	48.0113
GOV	0.2943	0.2047	0.1050	1.3538
OLD	0.1112	0.0280	0.0498	0.1880
UROD	0.0329	0.0311	-0.0326	0.1294

3.3 Model design

Based on the results of the Hausman test, the model significantly rejects the random effects model. Therefore, this study employs the fixed effects model to analyze the impact of internet development on the rural-urban income gap, as specified below:

$$URID_{it} = \beta_1 INT_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 GOV_{it} + \lambda_i + \varepsilon_{it} \quad (1)$$

In Equation (1), $URID_{it}$, INT_{it} , IND_{it} , FDI_{it} and GOV_{it} respectively represent the rural-urban income disparity, internet development, industrial structure, level of foreign direct investment, and government expenditure for the i th province in the t th year ($i = 1, 2, \dots, 31; t = 2013, \dots, 2021$). $\beta_1 - \beta_4$ represents the regression coefficients corresponding to the variables. λ_i denotes the intercept term for individual fixed effects, and ε_{it} represents the disturbance term that varies across individuals and time. We assume that $\{\varepsilon_{it}\}$ is independently and identically distributed (i.i.d.) and uncorrelated with λ_i .

To investigate the moderating effect of population aging on the impact of internet development on rural-urban income gap, this study introduces the population aging variable and its interaction term with internet development into Equation (1). The regression model is as follows:

$$URID_{it} = \delta_1 INT_{it} + \delta_2 OLD_{it} + \delta_3 OLD_{it} \times INT_{it} + \delta_4 IND_{it} + \delta_5 FDI_{it} + \delta_6 GOV_{it} + \varphi_i + \nu_{it} \quad (2)$$

$$URID_{it} = \delta_1 INT_{it} + \delta_2 UROD_{it} + \delta_3 UROD_{it} \times INT_{it} + \delta_4 IND_{it} + \delta_5 FDI_{it} + \delta_6 GOV_{it} + \varphi_i + \nu_{it} \quad (3)$$

In Equation, OLD_{it} and $UROD_{it}$ represent the level of population aging and the disparity in aging between urban and rural areas for the i th region in the t th year. The coefficient $\delta_1 - \delta_6$ corresponds to these variables. The term φ_i denotes individual fixed effects, while ν_{it} represents the disturbance term.

4. Empirical Results and Analysis

To ensure the reliability of the empirical results, stability and multicollinearity tests were conducted for all variables in the study. The results indicate that all variables are stable, and there are no serious multicollinearity issues among them. Additionally, cluster-robust standard errors were employed to mitigate the problem of overestimating the significance of explanatory variable coefficients in the presence of heteroscedasticity and autocorrelation.

4.1 Baseline Regression Analysis

The estimated results of the overall impact of internet development on rural-urban income gap are presented in Table 3, column 2. The coefficient of internet development is -37.7942, significant at the 1% level, indicating that internet development significantly narrows the rural-urban income gap. On the one hand, internet development enhances the efficiency of information flow, reducing information disparities between rural and urban areas. It brings advanced agricultural production technologies and modern scientific production concepts to farmers. Utilizing internet technologies such as big data, it analyzes agricultural production conditions and the agricultural product sales market, enabling timely adjustments and optimization of production decisions, reducing production blindness, and improving agricultural productivity. This increases rural residents' income from the supply side of agricultural production, thereby narrowing the rural-urban income gap. On the other hand, the internet broadens the sales channels for agricultural products through e-commerce and live-streaming economies. The long tail market brought about by internet development also expands the market for specialty agricultural products. This increases rural residents' income from the sales side of agricultural production, thereby reducing the rural-urban income gap. Furthermore, with the information dividends brought about by the internet, rural residents' human capital can be enhanced, narrowing the gap in education levels between urban and rural residents. Accessing employment information through online platforms reduces information disparities in the urban-rural labor market. Digitally inclusive financial services, born from the internet, lower the cost of capital acquisition for rural residents and increase their entrepreneurial opportunities. These three pathways increase rural residents' income from non-agricultural employment and entrepreneurship, thereby narrowing the rural-urban income gap, and hypothesis 1 above is confirmed.

The regression results of the impact of internet development on rural-urban income gap across different dimensions are shown in columns 3-6 of Table 3. Among them, the dimensions of infrastructure, commercial scale, and development potential exhibit significant inhibitory effects on rural-urban income gap, while the data-carrying dimension is not significant. Specifically, the impact of internet infrastructure development is significant at the 1% level, indicating that laying, upgrading, and improving internet infrastructure can deepen internet penetration, expand coverage to more remote rural areas, and solidify the foundation of internet

poverty reduction effects. The impact of internet commercial scale has passed the significance test at the 1% level, suggesting that expanding the commercial scale of the internet helps increase the usage rate of digital trading platforms in the region, broaden the sales channels for agricultural products, reduce transaction costs, increase household income, and narrow income gap. The impact of development potential is also significant at the 1% level. The richer accumulation of capital and human resources related to internet development, the more conducive it is to further development and breakthroughs of the internet, and better harnessing the economic effects of the internet.

Table 3: Regression results of the impact of internet development level and its sub-dimensions on urban-rural income gap

Variables	Overall level	Internet Infrastructure	Data Carrying Capacity	Commercial Scale	Development Potential
INT	-0.3779*** (-2.78)				
INF		-2.9939*** (-4.66)			
IFD			-0.1105 (-0.90)		
CMS				-1.1271*** (-4.15)	
PFD					-1.9219*** (-5.82)
IND	-2.2826* (-1.72)	0.2338 (0.20)	-3.6229*** (-2.82)	-2.4135* (-1.84)	-1.4118 (-1.10)
FDI	-0.0036*** (-3.47)	-0.0038*** (-5.07)	-0.0031** (-2.51)	-0.0038*** (-3.60)	-0.0034*** (-3.82)
GOV	1.2179*** (3.78)	1.2641*** (4.23)	1.1820*** (3.47)	1.2219*** (3.94)	1.2088*** (3.92)
Cons	4.5276*** (3.82)	2.4801** (2.35)	5.6227*** (4.82)	4.6140*** (3.92)	3.7254*** (3.23)
N	279	279	279	279	279
R ²	0.3507	0.5116	0.2553	0.3405	0.4045

Note: ***, **, * respectively represent significance at the 1%, 5%, 10% level, with the t-statistic values in parentheses.

4.2 Regional Heterogeneity Analysis

This study divides the sample into four groups: Northeast, East, Central, and West, for regional comparative analysis⁵. The regression results are shown in Table 4. The results indicate that internet development in all regions significantly reduces rural-urban income gap. However, the reduction effect in the East region is significantly lower than in the other regions (Northeast, Central, and West). There is no significant difference in the size of the internet's impact among the three regions. The reason for this is that the East region consists mainly of economically developed coastal areas with abundant resources such as talents and funds. The rural areas in these regions are relatively well-developed. Therefore, the internet has a smaller effect on reducing rural-urban income gap in the East region. In contrast, the Northeast, Central, and West regions are relatively economically underdeveloped compared to the East region, with larger rural-urban income gap. Due to geographical, social, and economic constraints, the pathways for rural residents to increase income are limited in these regions. Their means of reducing rural-urban income gap are relatively limited, often relying on government transfers. The avenues for rural income enhancement are relatively scarce, and the coverage and depth of the internet are insufficient. Therefore, there is considerable potential for internet development to empower and uplift these regions, leading to a more substantial reduction in rural-urban income gap.

Table 4: Regression results of regional internet development impact on urban-rural income disparity

Variables	Northeast	East	Central	West
int	-0.9589*	-0.1889**	-0.9626***	-0.9505***
	(-3.72)	(-2.71)	(-10.12)	(-3.16)
Control Variables	Control	Control	Control	Control
Cons	1.7463**	7.7554***	1.8982**	3.6342*
	(6.64)	(8.21)	(3.47)	(1.86)
N	27	90	54	108
R ²	0.7460	0.7479	0.6804	0.5358

Note: ***, **, * respectively represent significance at the 1%, 5%, 10% level, with the t-statistic values in parentheses.

⁵ Northeast region: Heilongjiang, Jilin, Liaoning; East region: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan; Central region: Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan; West region: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

4.3 Moderation Effect Analysis

In this study, an interaction term between the level of internet development and population aging is added to the model to examine the moderating effect of population aging on the relationship between internet development and the urban-rural income gap. The results, as shown in Table 5 Column 1, indicate a significant positive effect of the interaction term between population aging and internet development on the urban-rural income gap, while the coefficient of internet development on the urban-rural income gap is significantly negative at the 1% level. The elderly population, due to declines in learning and cognitive abilities, tends to exhibit psychological resistance and encounter learning difficulties when encountering new phenomena such as the internet. This significantly affects the application and popularization of the internet among the elderly population. Given the differences in cognition and education between rural and urban elderly residents, rural elderly individuals are less likely to embrace the changes brought about by the internet, thus hindering the internet's ability to narrow the urban-rural income gap, and hypothesis 2 above is confirmed.

Based on the theoretical analysis presented earlier, the imbalance in the aging process between urban and rural areas is identified as a significant factor inhibiting the internet's ability to narrow the urban-rural income gap. Therefore, introducing the disparity in aging between urban and rural areas as a moderating variable, the regression results are shown in Table 5 Column 2. The results indicate that the interaction term between the disparity in aging between urban and rural areas and internet development is significantly positive, while it is opposite to the coefficient of internet development. This suggests that the uneven aging process between urban and rural areas is one of the reasons for weakening the effect of internet development in narrowing the urban-rural income gap.

The imbalance in development between urban and rural areas leads to the migration of labor from rural to urban areas, resulting in an expansion of the proportion of the elderly population in rural areas. The aging process in rural areas significantly outpaces that in urban areas, and this trend continues to widen. The barriers to internet usage among the elderly population exacerbate this situation. Consequently, the growth effects of internet development on agricultural and non-agricultural income for rural households are weakened. In contrast, the impact on urban areas is relatively minor due to the slower aging process. Thus, the disparity in age between urban and rural areas undermines the impact of internet development on the urban-rural income gap, and hypothesis 3 above is confirmed.

Table 5: Regression results of the moderating effect of population aging

Variables	Population Aging	Disparity in Urban-Rural Population Aging
INT	-0.1675**	-0.2880**
	(-2.41)	(-2.31)
OLD	-4.1162***	
	(-7.69)	
INT*OLD	6.1878***	
	(4.37)	
UROD		-2.5668***
		(-4.87)
INT*UROD		2.8041**
		(2.18)
Control Variables	Control	Control
Cons	3.6650***	4.2272***
	(4.71)	(4.17)
N	279	279
R ²	0.6866	0.5327

Note: ***, **, * respectively represent significance at the 1%, 5%, 10% level, with the t-statistic values in parentheses.

4.4 Endogeneity Issues

Considering the potential bidirectional causality inherent in the model, which may affect the reliability of coefficient estimation, this study employs instrumental variable (IV) regression to address endogeneity concerns. The number of mobile phone base stations is utilized as an instrumental variable in a two-stage least squares estimation. The quantity of mobile phone base stations reflects the level of communication infrastructure within a region, and an increase in mobile phone base stations facilitates enhanced internet coverage, thereby boosting the level of internet development, consistent with the relevance assumption of instrumental variables. Moreover, the number of mobile phone base stations does not directly affect the urban-rural income gap, meeting the exogeneity requirement. Results indicate that the coefficient of internet development remains significantly negative at the 1% level, and the IV regression passes the tests for weak instrument and under identification. Hence, the conclusion that internet development mitigates the urban-rural income gap remains reliable, accounting for endogeneity concerns.

4.5 Robustness Checks

The stability of estimation results may be affected by different methods of constructing variable evaluation indicator systems and model settings. To enhance the reliability of research conclusions, the following robustness checks are conducted: Firstly, the main proxy variable is replaced with the number of internet users (IIU) as a proxy for internet development, while keeping other variables

constant for regression. Secondly, a 1% trimmed regression is performed for all variables before and after estimation. Thirdly, the sample period is shortened to 2014-2021 for model re-estimation. Following these empirical tests, the robustness check results, as shown in Table 6, indicate that neither the sign nor the significance of the coefficient of internet development level has undergone substantive changes, demonstrating the robustness of the estimation results.

Table 6: Robustness checks

Variable	Replacement Variables: IIU	Tail Trimming	Shortening the Sample Interval
INT		-0.3343***	-0.3655***
		(-2.79)	(-2.83)
IIU	-0.9895***		
	(-9.65)		
Control Variables	Control	Control	Control
Cons	1.6440**	4.5905***	3.4659***
	(2.42)	(4.41)	(3.17)
N	279	279	248
R ²	0.7240	0.4061	0.3538

Note: ***, **, * respectively represent significance at the 1%, 5%, 10% level, with the t-statistic values in parentheses.

5. Conclusions and Recommendations

Entering the era of comprehensive prosperity, achieving common prosperity for all people has become a new urgent demand for the Chinese people. With the advent of the information and digital age, internet development has provided an effective impetus for narrowing the urban-rural income gap. This study examines the impact of internet development on the urban-rural income gap using panel data from 31 provinces and autonomous regions in China from 2013 to 2021 and further explores the moderating effect of population aging on this impact. The findings are as follows: 1. Internet development significantly narrows the urban-rural income gap, with this effect being particularly significant in the dimensions of infrastructure, commercial scale, and development potential. 2. Regional heterogeneity tests indicate that internet development in the northeastern, central, and western regions significantly narrows the urban-rural income gap to a greater extent than in the eastern region. 3. The deepening of population aging inhibits the contraction effect of internet development on the urban-rural income gap, with the imbalance in urban-rural aging processes being a key factor inhibiting the role of the internet in narrowing the urban-rural income gap. Based on these conclusions, the following recommendations are proposed:

Firstly, it is imperative to vigorously promote the development and utilization of the internet, while coordinating the regional allocation of China's internet resources. Continued efforts should be made to enhance internet infrastructure construction, with simultaneous attention to commercial applications of the internet and talent cultivation. Deepening internet applications and accelerating the grasp of digitization trends are essential for future internet development. Alongside development, emphasis should be placed on strengthening internet governance, including classification and hierarchical supervision of data, constructing a data security governance system, and establishing new orders in cyberspace to better serve social development using network information technology. Additionally, efforts should be directed towards enhancing internet development in relatively underdeveloped regions such as the northeast, central, and western areas to prevent the internet from becoming a new cause of inequality between regions. Promoting balanced regional internet development will contribute to further narrowing the urban-rural income gap.

Secondly, it is crucial to accelerate the development of rural internet infrastructure and continue implementing the strategy for rural revitalization through digitalization. Establishing special funds for rural internet development and increasing investment efforts will expedite the pace of rural internet construction, thereby expanding the effective coverage of fiber optic and broadband networks in rural areas. Promoting the deep integration of internet technology and agriculture, particularly by applying technologies such as 5G and big data in agriculture, will optimize farm production decisions and enhance agricultural productivity. Additionally, fostering the development of rural e-commerce and expanding channels for selling agricultural products will harness the power of internet technology to increase rural household income. Leveraging internet technology to improve the information acquisition capabilities and human capital levels of rural residents will facilitate diversified opportunities for rural employment and entrepreneurship.

Thirdly, advancing the age-friendly transformation of the internet and continuously promoting digital inclusion are imperative. Given the increasingly severe aging population in China, the demand for internet usage among the elderly should be prioritized. It is essential to address the practical pain points and needs of the elderly population in today's digital era. Initiatives should be undertaken to provide information accessibility services led by the government, with social participation and family support, facilitating the elderly in overcoming the "digital divide." Moreover, continuous efforts should be made to develop age-friendly applications and innovative age-friendly technologies, aiming to lower the technological barriers and operational difficulties associated with internet usage. These endeavors will contribute to advancing inclusive information society development and creating a user-friendly internet environment for the elderly population.

References

- [1] Ji X., Xu J. and Zhang H. (2023). Environmental effects of rural e-commerce: A case study of chemical fertilizer reduction in China. *Journal of Environmental Management*, vol. 326(Pt A), no. A, pp. 116713-116713.
- [2] Gao Y., Zang L. and Sun J. (2018). Does computer penetration increase farmers' income? An empirical study from China. *Telecommunications Policy*, 42(05), pp. 345-360.
- [3] Peng C., Ma B. and Zhang C. (2021). Poverty alleviation through e-commerce: Village involvement and demonstration policies in rural China. *Journal of Integrative Agriculture*, 20(04), pp. 998-1011.
- [4] Forman C., Goldfarb A. and Greenstein S. (2012). The internet and local wages: A puzzle. *The American Economic Review*, 102(01), pp. 556-575.
- [5] Liu J. (2017). An empirical study of the urban-rural digital divide that continues to widen the urban-rural income gap. *Statistics & Decision*, 207(10), pp. 119-121.
- [6] Chen W. and Wu Y. (2021). Digital economy's development, digital divide and the income gap between urban and rural residents. *South China Journal of Economics*, 2021(11), pp. 1-17.
- [7] Wang J. Wang S. and Feng B. (2017). The effect of population aging on rural-urban income inequality: based on the perspective of the evolution of China's dual economic structure. *The American Economic Review*, 2017(09), pp. 117-134.
- [8] Yao Y. (2021). How does population aging affect urban-rural income inequality. *Modern Economic Research*, 2021(04), pp. 33-42.
- [9] Zeng L. and Jiang W. (2020). Age structure of population, social security level and the income gap between urban and rural areas: based on GMM estimation method and panel threshold regression. *Northwest Population Journal*, 41(5), pp. 46-58.
- [10] Wang D. and Cao J. (2019). The impact of Internet development on China's total factor energy efficiency and its network effects. *China Population, Resources and Environment*, 29(01), pp. 86-95.
- [11] Bojnec Š. and Fertő I. (2015). Impact of the Internet on Manufacturing Trade. *Journal of Computer Information Systems*, 50(01), pp. 124-132.
- [12] Choi C. (2010). The effect of the Internet on service trade. *Economics Letters*, 109(02), pp. 102-104.
- [13] Tian Y. and Feng C. (2023). How does internet development drive the sustainable economic growth of China? Evidence from internal-structural perspective of green total-factor productivity. *Science of The Total Environment*, 887(20), pp. 164125.
- [14] Wang K., Sun T., Xu R., Miao Z. and Cheng Y. (2022). How does internet development promote urban green innovation efficiency? Evidence from China. *Technological Forecasting and Social Change*, 184, pp. 122017.

- [15] Li X. and He C. (2019). Research on the impacts of Internet plus era on the innovative driving force in manufacturing. *Journal of International Economic Cooperation*, 2019(5), pp. 36-47.
- [16] Zeng Z. (2019). Influence of dual economic structure on the income gap between urban and rural residents under the process of marketization. *Inquiry into Economic Issues*, 2019(12), pp. 102-111.
- [17] Ogutu, S.O., Okello, J.J. and Otieno, D.J. (2014). Impact of Information and Communication Technology-Based Market Information Services on Smallholder Farm Input Use and Productivity: The Case of Kenya. *World Development*, 64, pp. 311-321.
- [18] Ullah A., Arshad M., Kächele H., Khan A., Mahmood N. and Müller K. (2023). Information asymmetry, input markets, adoption of innovations and agricultural land use in Khyber Pakhtunkhwa, Pakistan. *Land Use Policy*, 90, pp. 104261.
- [19] Leng X. (2022). Digital revolution and rural family income: Evidence from China. *Journal of Rural Studies*, 94, pp. 336-343.
- [20] Wang J., Yang G. and Zhou C. (2024). Does internet use promote agricultural green development? Evidence from China. *International Review of Economics & Finance*, 1.
<https://www.sciencedirect.com/science/article/pii/S1059056024001746>
- [21] Nawab Khan N., Ray R.L., Zhang S., Osabuohien E. and Ihtisham M. (2022). Influence of mobile phone and internet technology on income of rural farmers: Evidence from Khyber Pakhtunkhwa Province, Pakistan. *Technology in Society*, 68, pp. 101866-101866.
- [22] Demertzis M., Merler S. and Wolff G.B. (2018). Capital Markets Union and the Fintech Opportunity. *Journal of Financial Regulation*, 4(01), pp. 157–165.
- [23] Xie H., Zhang J. and Shao J. (2023). Difference in the influence of internet use on the relative poverty among farmers with different income structures. *Economic Analysis and Policy*, 78, pp. 561-570.
- [24] Min S., Liu M. and Huang J. (2020). Does the application of ICTs facilitate rural economic transformation in China? Empirical evidence from the use of smartphones among farmers. *Journal of Asian Economics*, 70, pp. 101219-101219.
- [25] Zhang T. and Cai K. (2021). Does Digital inclusive Finance Narrow the Consumption Gap between Urban and Rural Residents? Empirical Analysis Based on Chinese Provincial Panel Data. *On Economic Problems*, 2021(09), pp. 31-39.
- [26] Yuan Z. and Jia G. (2021). Profiling the digital divide of the elderly based on Internet big data: evidence from China. *Data Science and Management*, 3, pp. 33-43.
- [27] Yuan L., Yu B., Gao L., Du M., Lv Y., Liu X. and Sun J. (2023). Decomposition analysis of health inequalities between the urban and rural oldest-old populations in China: Evidence from a national survey. *SSM - Population Health*, 21, pp. 101325-101325.

- [28] Li J. and Wu M. (2020). The Quality of the Urban and Rural Population Aging in China: Differences and Forecasts. *Journal of Macro-quality Research*, 8(05), pp. 1-13.
- [29] Ge J. Wang M. and Tang Y. (2022). Rural industrial Integration, Consumption of Urban and Rural Residents and Urban-rural Income Gap: Can Both Efficiency and Fairness Be Achieved?. *Journal of Macro-quality Research*, 2022(03), pp. 1-13.